Improving Traffic Signal Operations with High-Resolution Data

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Active Traffic Signal Management Workshop

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Outline

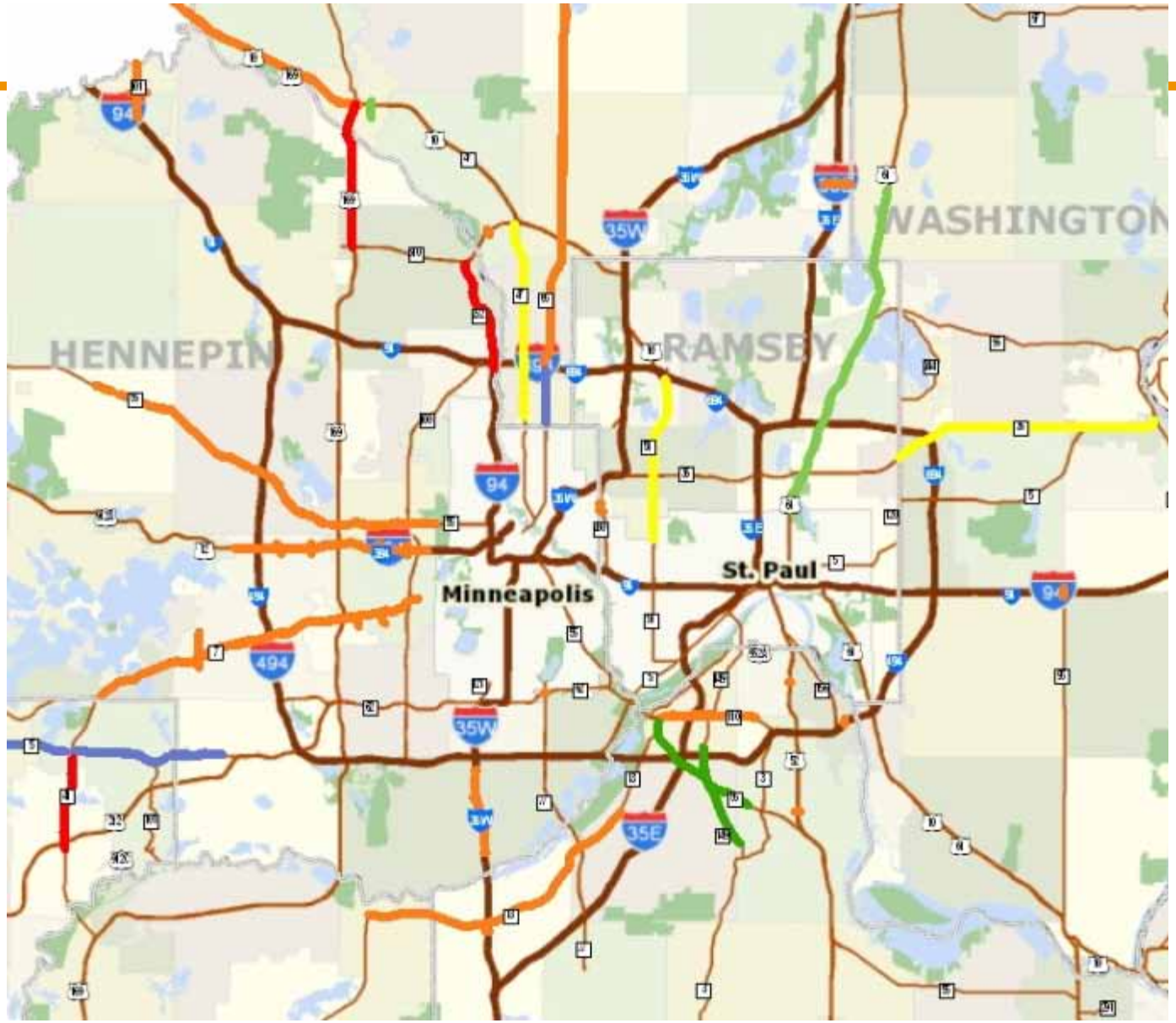
- MnDOT Metro District
- MnDOT Signal Operations Practice
- MnDOT Technical Needs

- High-resolution Data Collection
- Arterial Performance Measurement
- Conclusion and Future Works

MnDOT Metro District

- **700 signals**
  - **650 on comms**
    - **200 on i2/TACTICS**
    - **450 dial-up (Aries)**
  - **200 intersections viewed via cameras**
  - **Staff of 23 (maintenance & operations)**

MnDOT's System



Signal Timing & Optimization

- **Major Zones (Projects)**
  - **Retimed every 3 yrs**
    - **5-7 plans per day – Time-of-day**
    - **Consultant develop, MnDOT implemented**
  - **Performance Measures**
    - **Before/after evaluation travel times**
    - **Synchro/SimTraffic outputs**
      - **Delays, stops, travel times**
    - **Air quality (CMAQ)**

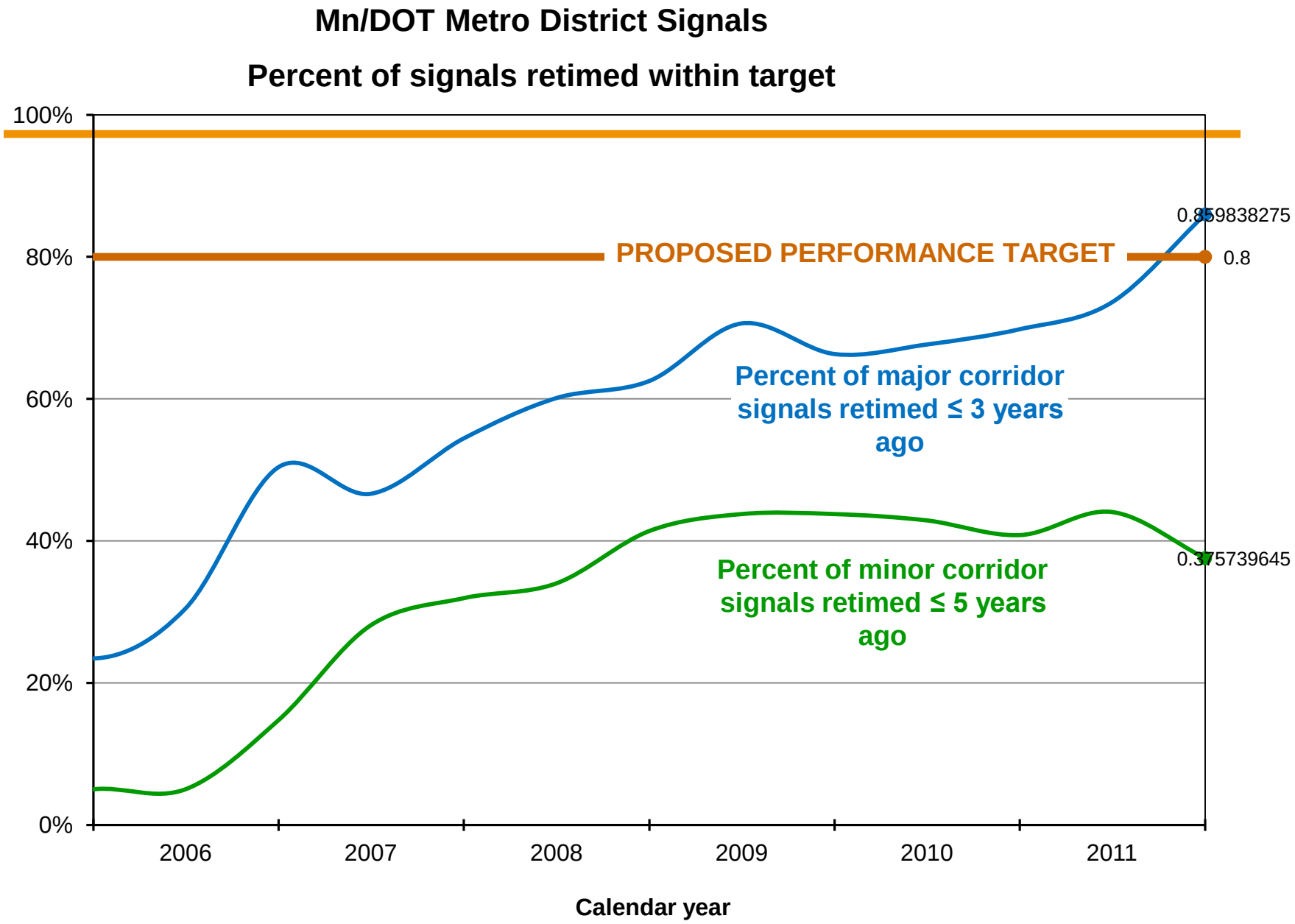
Signal Timing & Optimization

- **Minor Zones - Retimed every 5 yrs**
  - **MnDOT developed & implemented**
  - **Minimal evaluation performed**
    - **Synchro/SimTraffic**

MnDOT Metro Major Expressways

Hwy	Location	# signals	Last retimed	
MAJOR CORRIDOR PROJECTS: retime every 3 years				
5, 41	Chaska to Eden Prairie	29	Feb '09	**12 projects**
7	Minnetrista to St. Louis Park	31	Aug '11	**371 signals**
13	Prior Lake to Eagan	44	Sep '09	
36, 51	Roseville, North St. Paul to Stillwater	26	Apr '09	
55	Medina to Golden Valley	39	Sep '11	
55, 149, 3	Mendota Heights to Rosemount	24	Aug '10	
61	Maplewood to Hugo	23	Jan '09	
65	Columbia Heights to East Bethel	33	Jun '09	
169, 10, 47	Champlin to Ramsey	25	Jun '07	
212	Flying Cloud Dr, Eden Prairie Ring Rd	30	Mar '10	
252, 47	Brooklyn Park, Columbia Hts to Fridley	24	Oct '08	
494, 35W	Amer. Blvd, 76th/77th, N/S Cross St's	43	Jun '11	
MINOR CORRIDOR PROJECTS: retime every 5 years				
3	CR 50 to Hwy 50 in Farmington	2	never	**97 projects**
5	Granada Ave to Ideal Ave in Oakdale	5	never	**338 signals**
5	58th St to Croixwood Blvd in Stillwater	7	Oct '11	
5	Oak Ave to CR 59 in Waconia	7	Apr '11	
8	Greeway Ave to Oak St in Chisago Cty	10	Apr '11	
10	CR 7 N and S Ramps in Anoka	2	never	
10	Foley NR to 99th Ave in Coon Rapids	3	never	
10	Robinson to Northdale in Coon Rapids	3	Aug '07	

(actual spreadsheet continues, listing all 97 minor corridor projects)


Mn/DOT Metro District Signals
Percent of signals retimed within target
100%
80%
60%
40%
20%
0%
PROPOSED PERFORMANCE TARGET
0.8
0.859838275
Percent of major corridor signals retimed ≤ 3 years ago
Percent of minor corridor signals retimed ≤ 5 years ago
0.375739645
2006
2007
2008
2009
2010
2011
Calendar year

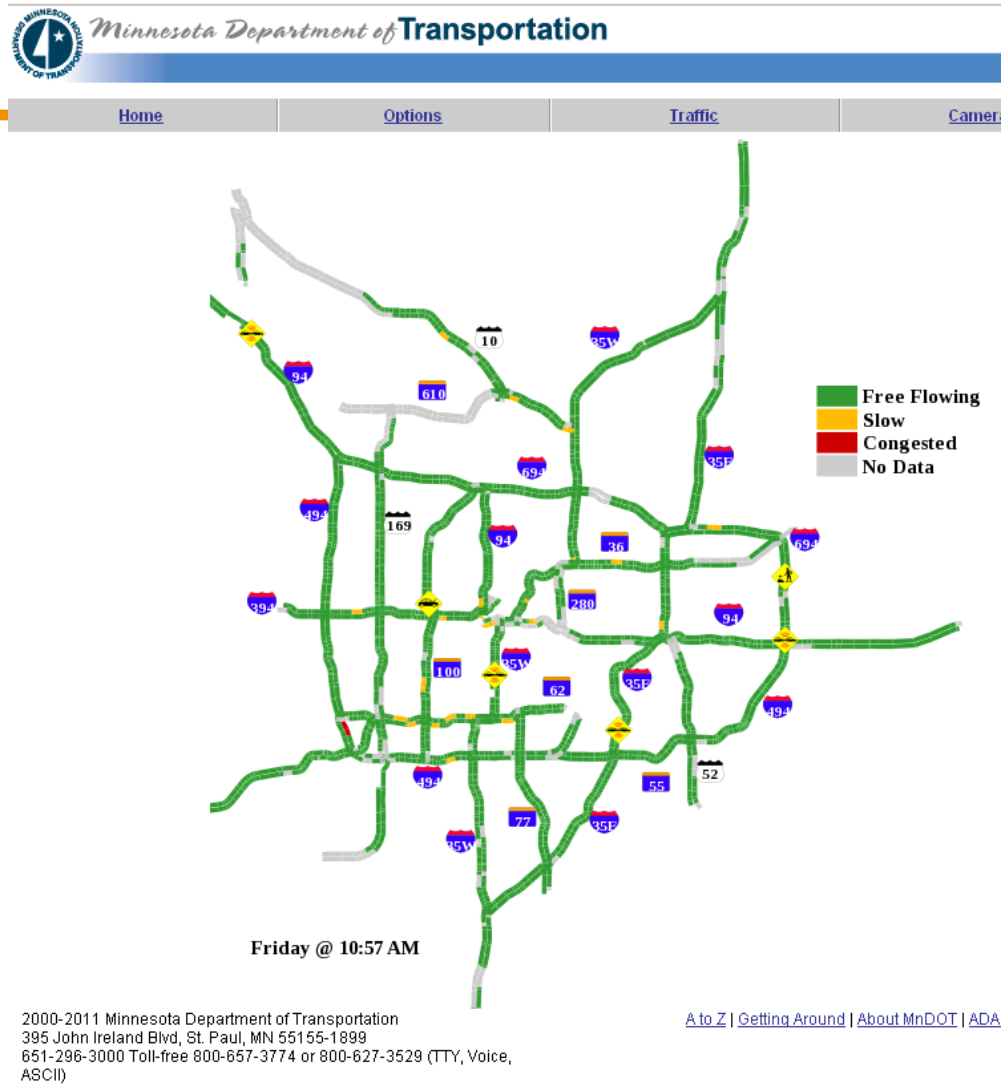
How are we doing
Do we know?

- **Ask staff –**
- **Ask public –**
- **Ask management-**

Freeway Management System in Metro

- Ramp metering, camera surveillance
- Changeable Message Signs
  - ***Travel Times***
- Incident Management
- Service Patrols
- Traveler Information/88.5 Traffic Radio/511
  - ***Congestion Map***
- Lane Control Signals/Value Pricing

- **Usually traveler information is available for freeways, so far NO arterial travel information is available.**
- **New technologies that uses smart-phone as traffic probe is promising but not mature**



Arterial Performance Measures

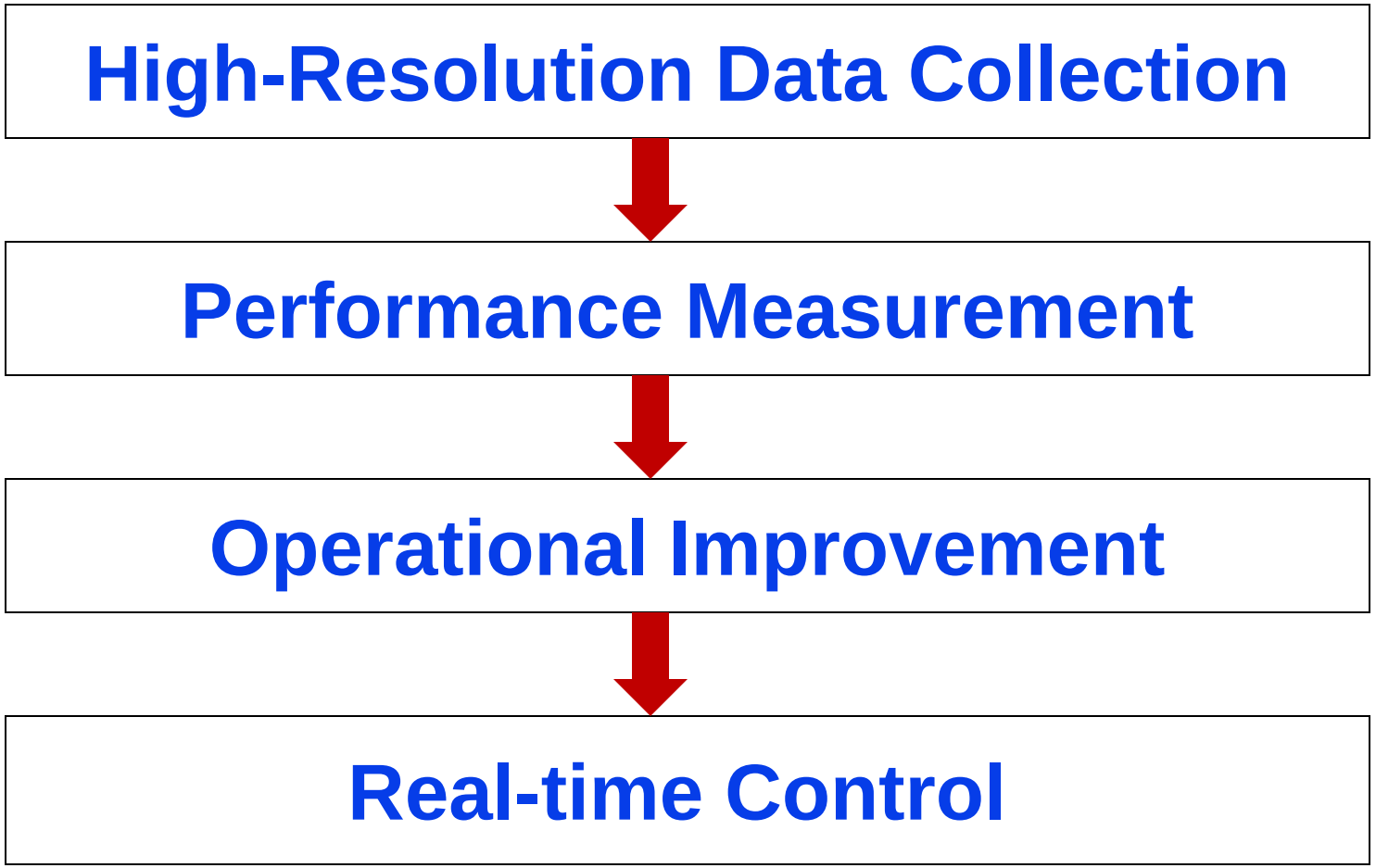
Public/Management

- Map (1000 words)
- Travel Times
- Something that's easily understood
  - Stops/mile
  - Signals/red

Operations

- Quick look at health of system
- Useable
- Use available data
- Viewable over time
- View – corridor, intersection, approach

Technology Development Roadmap



Technical Requirements

- **Passive data collection from existing infrastructure**
- **Compatible with different detector, controller and cabinet settings**
- **Capable of handling congested traffic conditions**

Ideally, for an Intelligent System

Data → **Information** → **Control**

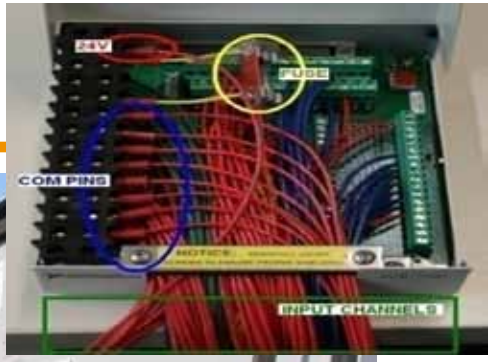
If you cannot tell the system performance yesterday, you cannot hope to manage your system today.

SMART-Signal: Systematic Monitoring of Arterial Road Traffic Signals

- An automatic and continuous data collection system from existing traffic signals
- A performance measurement system for intersection queue length and arterial travel time, especially under congested traffic conditions
- A performance tuning system for optimization of traffic signal parameters

1st Gen. Data Collection

Terminal Box



DAC

2nd Gen. Data Collection

Plug-and-play Implementation:

1. **Plug in SDLC Port.**
2. **Plug in power adapter.**
3. **Plug in Ethernet connection.**
4. **Turn on the power.**

To debug in the field:

1. **Connect your laptop with the device using the Serial Port.**
2. **Log into the field device using the Linux system.**

Event-Based Data

08:09:15.012, D8 on, 7.902s → Detector #8 on at 08:09:15.012; Vacant time is 7.902s

08:09:15.481, D8 off, 0.468s

08:09:16.761, G3 off, 29.389s → Green Phase #3 off at 08:09:16.761; Green duration time is 29.389s

08:09:16.761, Y3 on, 179.021s

08:09:17.620, D9 on, 2.686s

08:09:18.151, D10 on, 2.593s

08:09:18.307, D9 off, 0.687s → Detector #9 off at 08:09:18.307; Occupy time is 0.687s

08:09:18.823, D10 off, 0.671s

08:09:20.244, Y3 off, 3.482s → Yellow Phase #3 off at 08:09:20.244; Yellow duration time is 3.482s

08:09:21.649, D22 on, 80.953s

08:09:22.008, D22 off, 0.359s

08:09:23.242, G1 on, 172.806s → Green Phase #1 on at 08:09:23.242; Red duration time is 172.806s

Research Implementation Sites

- **11 intersections on France Ave. in Bloomington (March 07 – June 09)**
- **6 intersections on TH55 in Golden Valley (Feb. 08 – Sept. 09)**
- **3 intersections on PCD in Eden Prairie (Current)**
- **6 intersections in Pasadena, CA (Iteris, Current)**
- **13 intersections on TH13 (Current)**
- **10 intersections on TH55 (January 2012, Expected)**

Performance Measurement Algorithms

- **Queue length estimation**
  - **Delay, Level of Services, number of stops**

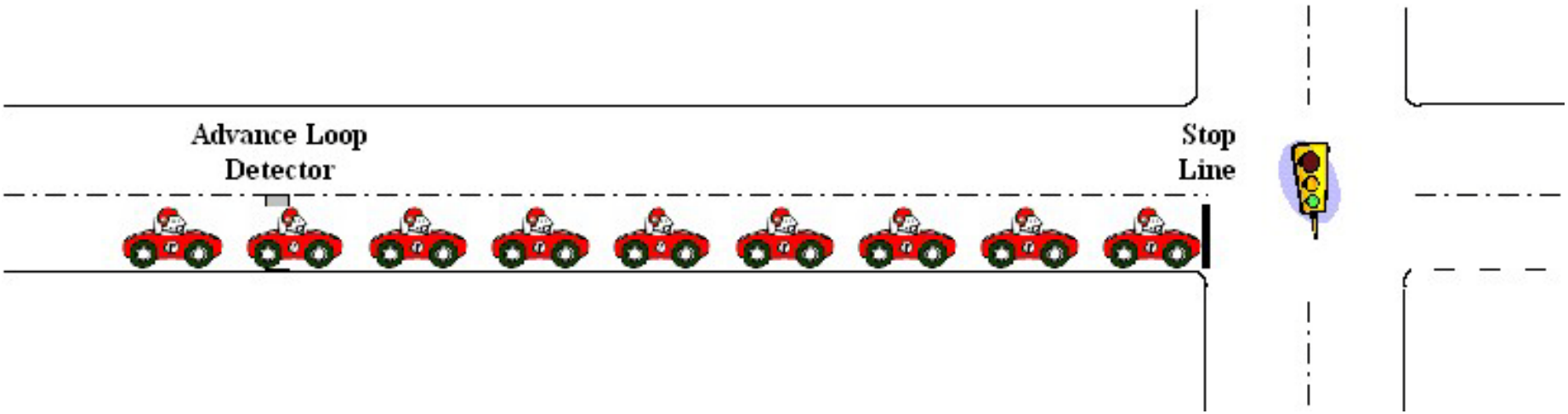
  (Transp. Res. Part C, 17(4), 412-427, 2009.)
- **Identification of oversaturated conditions**
  - **Oversaturation Severity Index (OSI)**

  (Transp. Res. Part C, 18(4), 626-638, 2010.)
- **Travel time estimation**
  - **Personal trip delay, number of stops, carbon footprint on travel**

  (Transp. Res. Part C, 17(1), 11-26, 2009.)

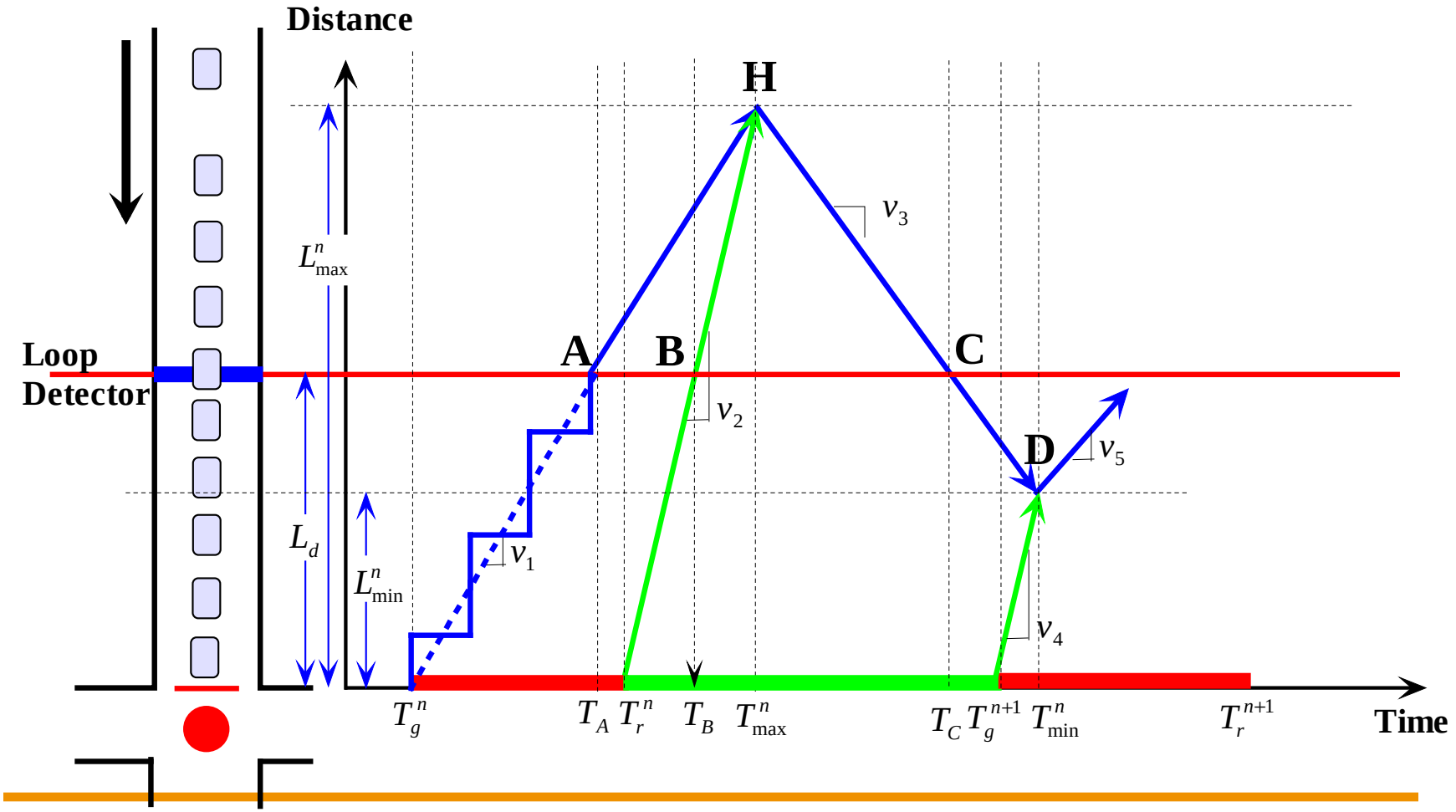
Queue Length Estimation

- Instead of traditional input-output approach, we estimate queue length by taking advantage of queue discharge process
- Based on LWR shockwave theory

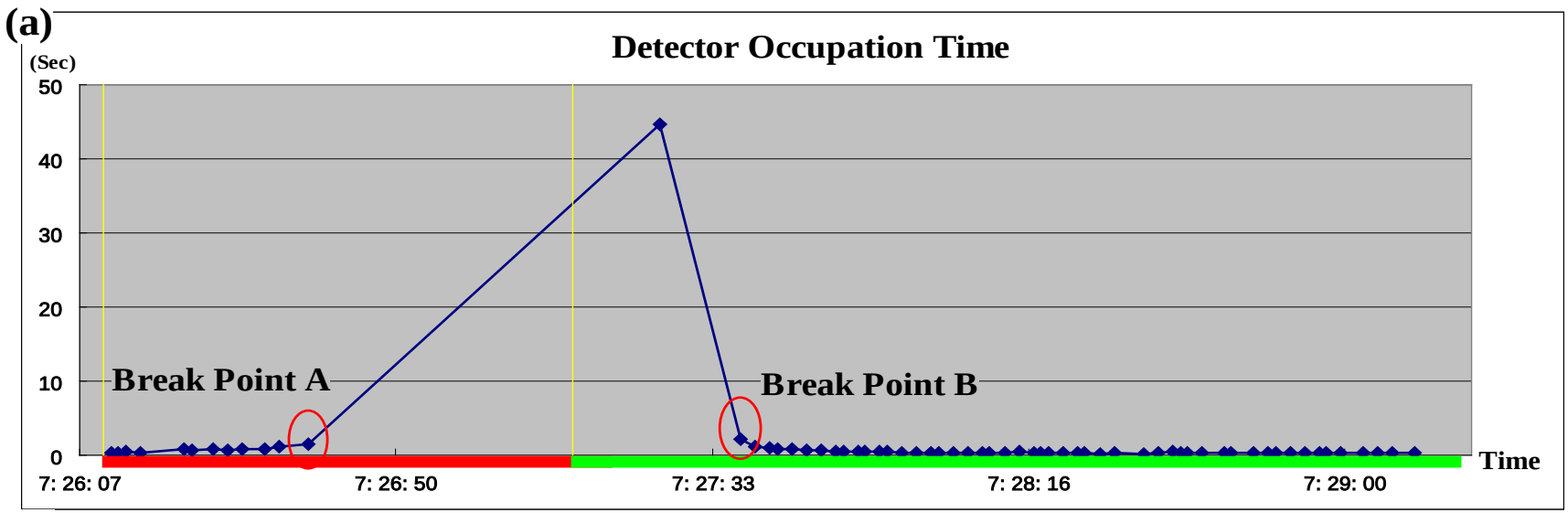


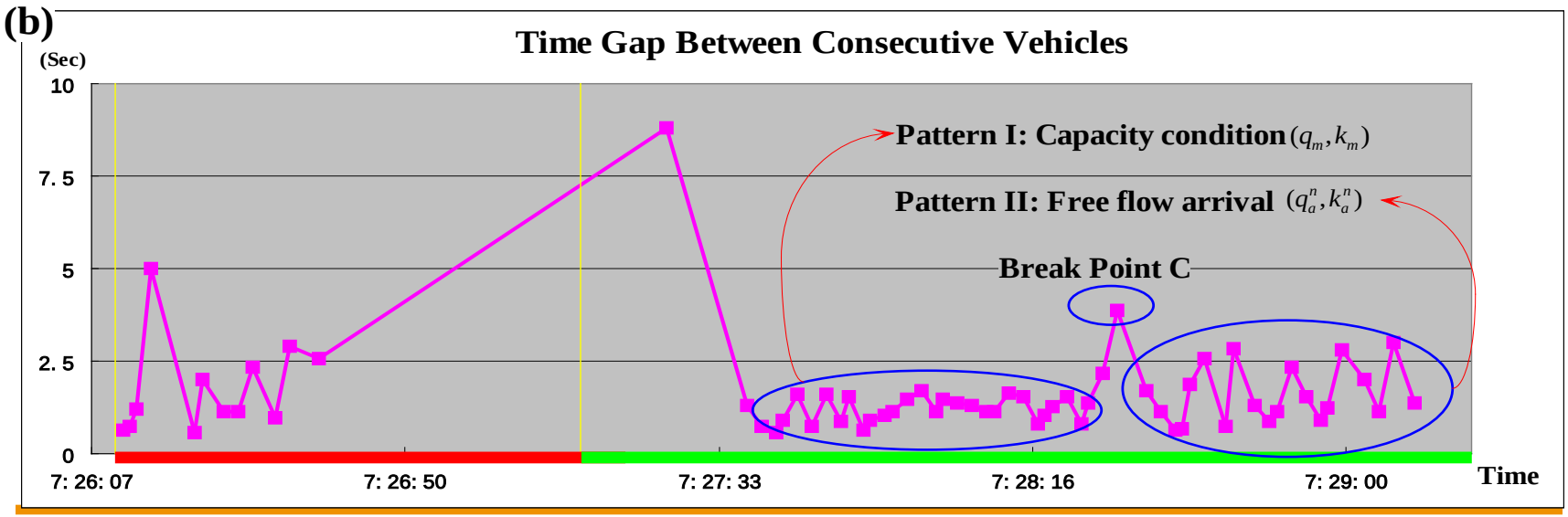
Queue Length Estimation

- Utilize the data collected by advance detector
- Identify Critical Points: A, B, C



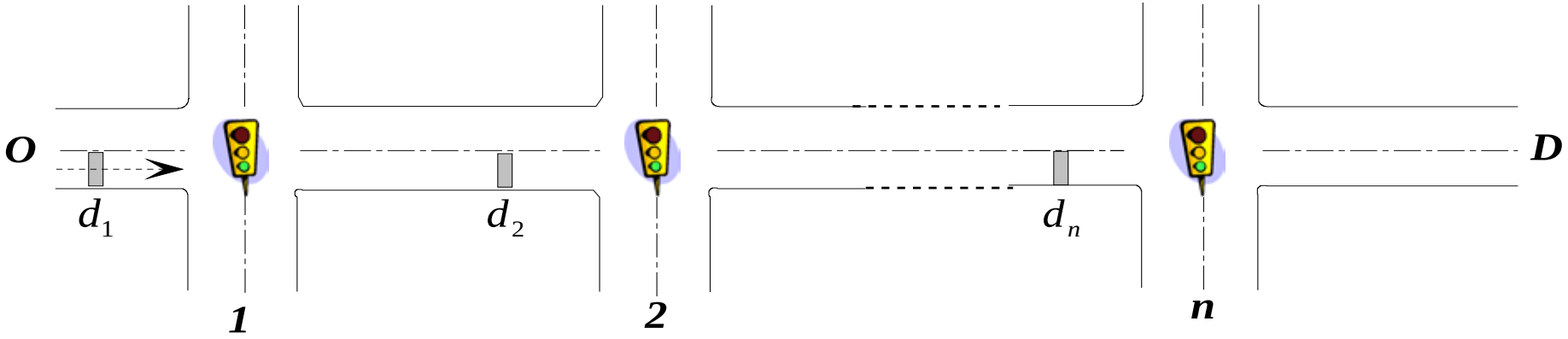
Break Point Identification from High-Resolution Detector Data



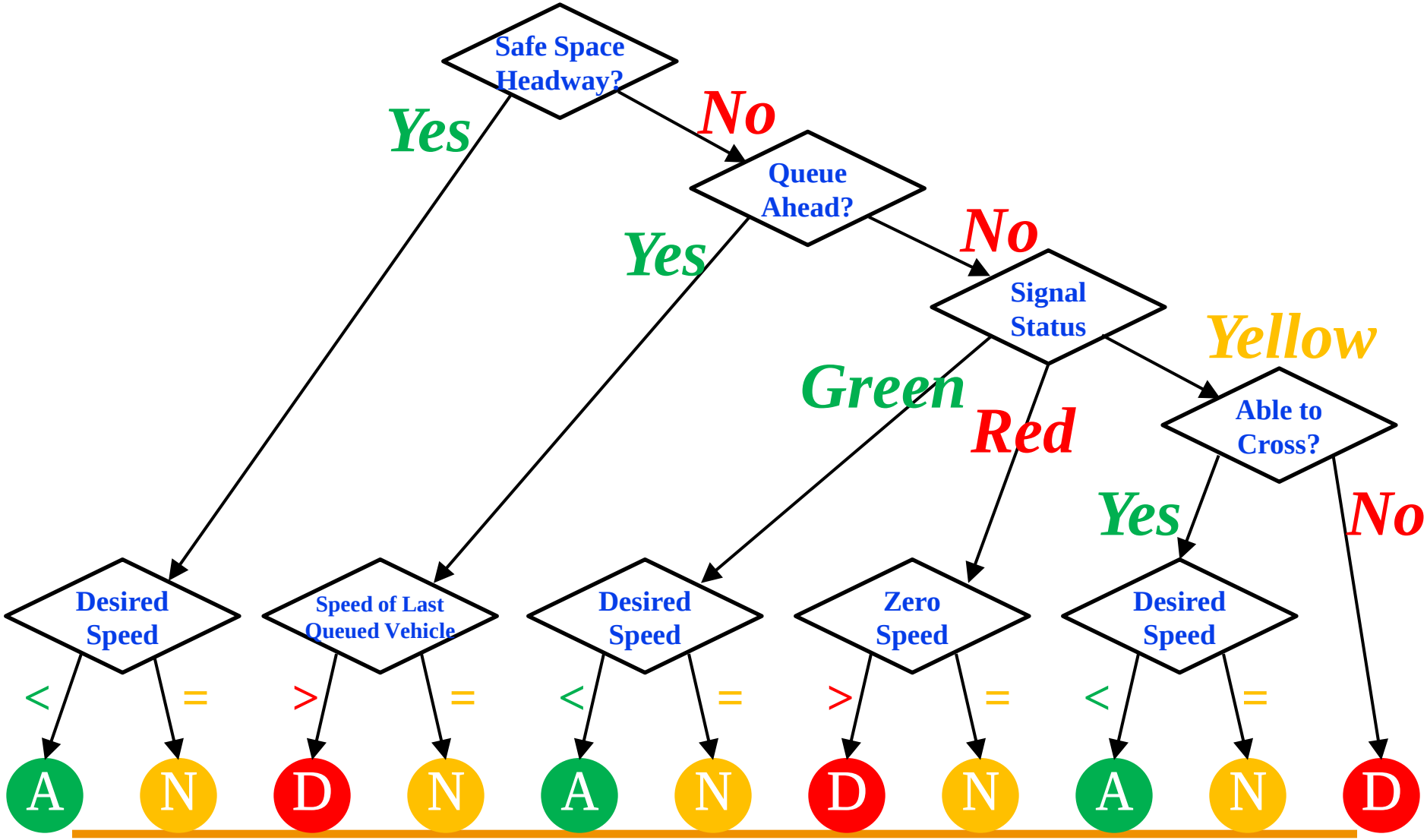


Travel Time Estimation

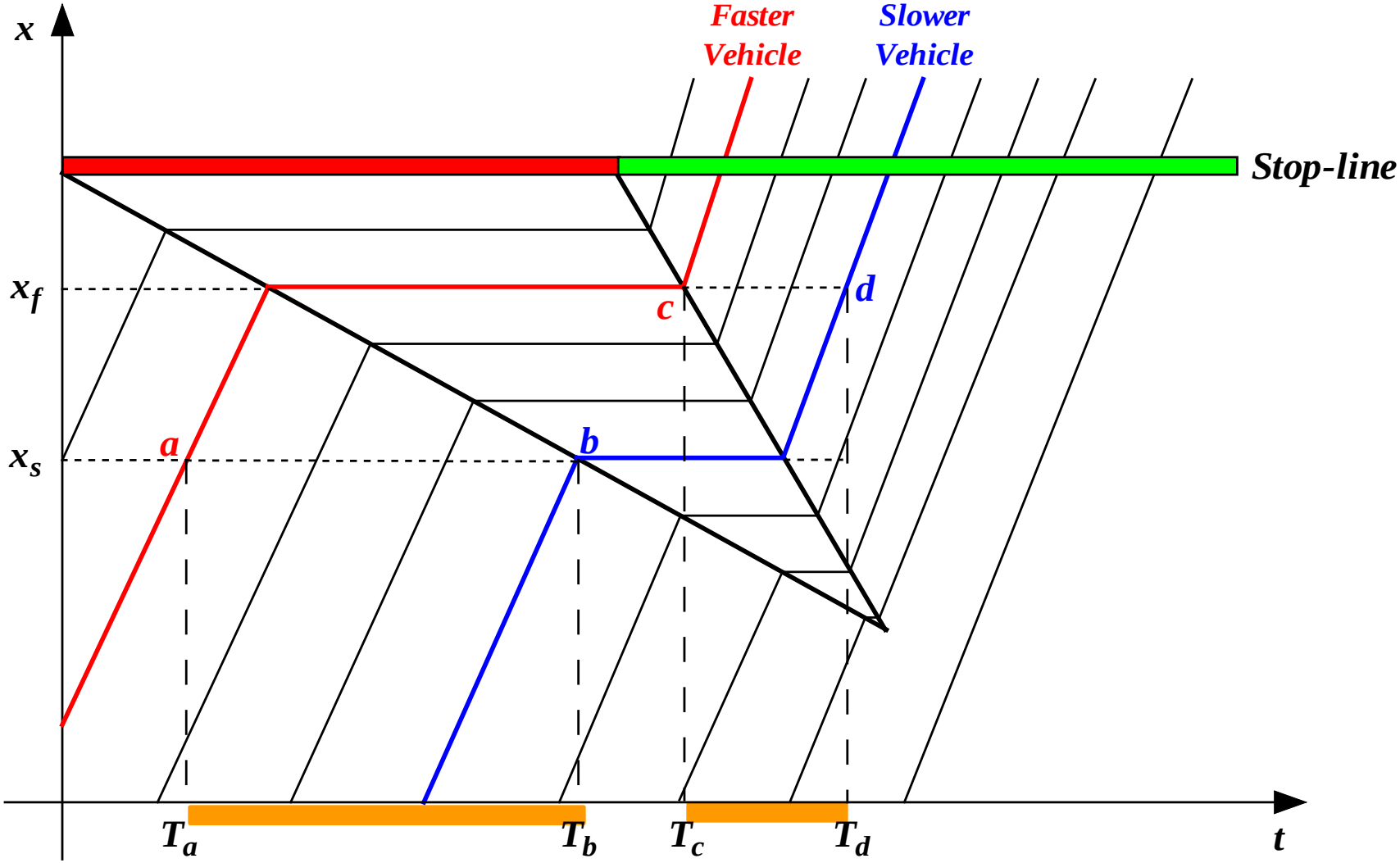
- **Track a virtual probe vehicle**
  - **Signal delay**
  - **Queuing delay**
  - **Acceleration/deceleration/no-speed-change**



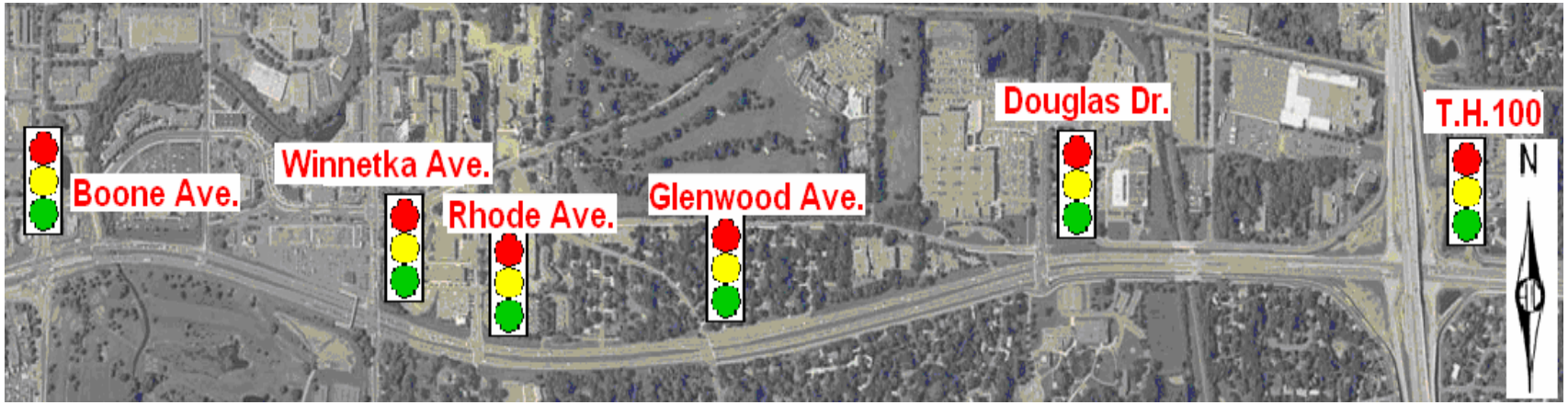
Maneuver Decision Tree

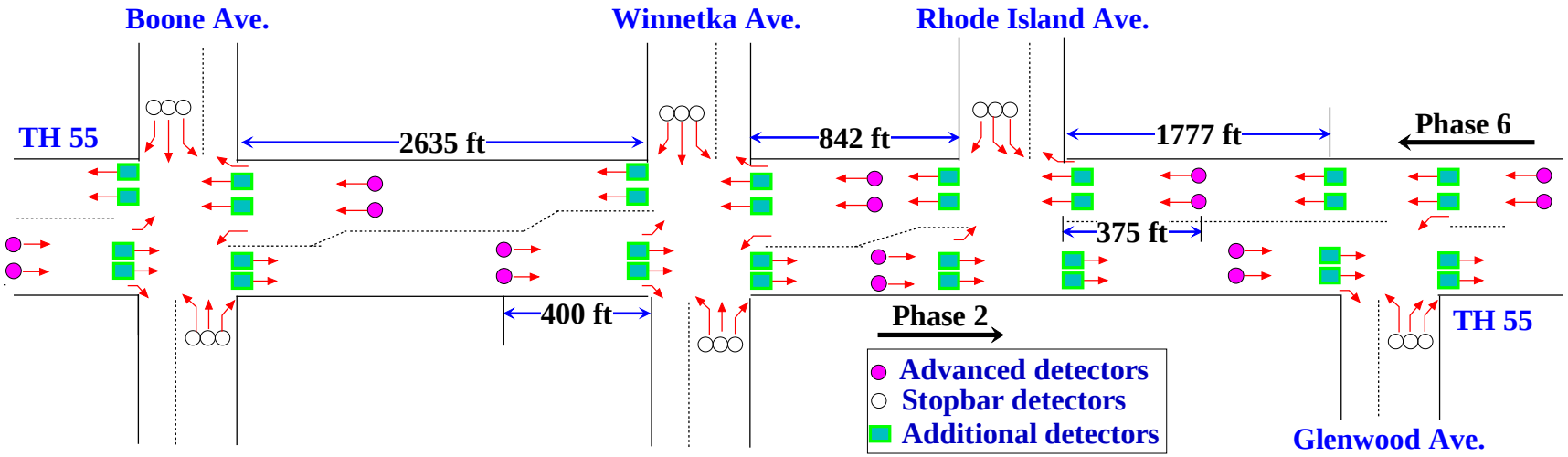


Self-Correction Property



Field Tests on TH55 in Minneapolis

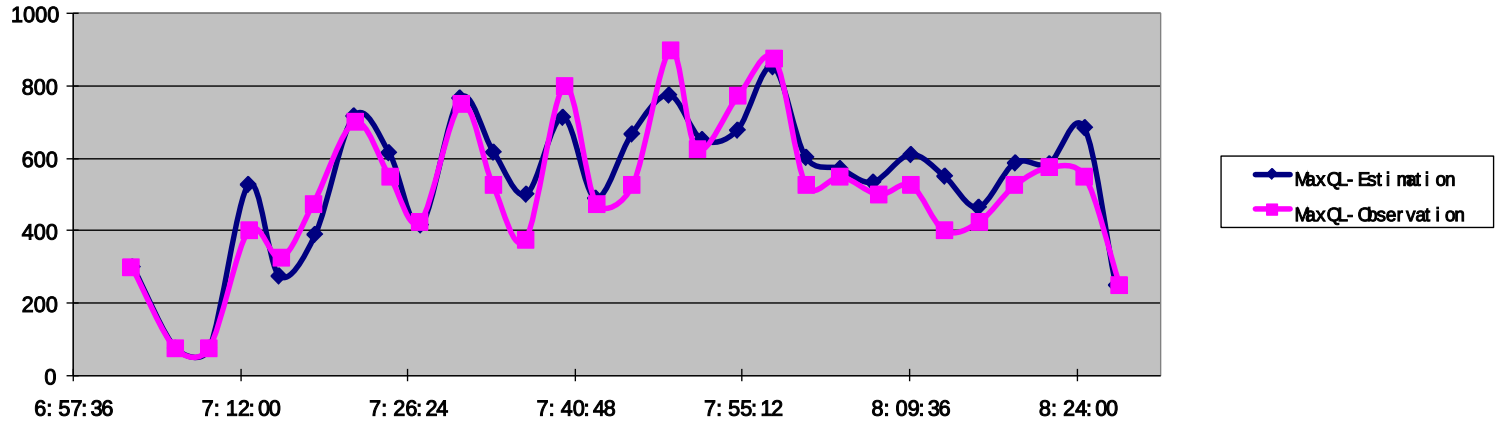


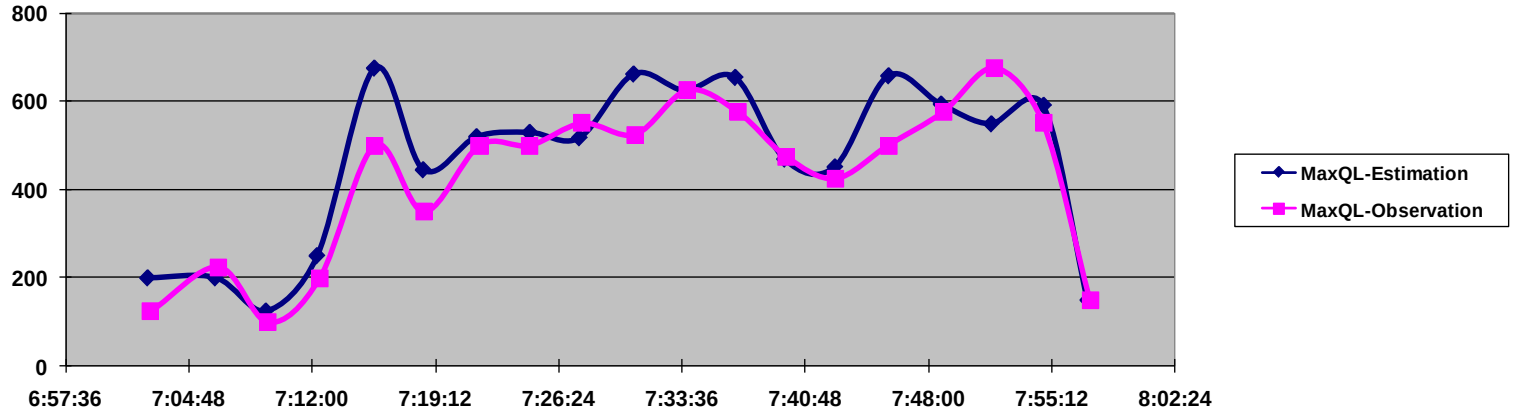


Independent Evaluation of Performance Measures on TH55

- **By Alliant Engr. Inc**
- **Queue length**
  - **Manually count the vehicles (Two persons per approach)**
  - **Four peak hours (July 22nd and 23rd, 2009)**
- **Travel time**
  - **Floating car method with GPS**
  - **Four peak hours (July 22nd and 23rd , 2009)**
  - **More than 70 runs**

Results – Maximum Queue Length





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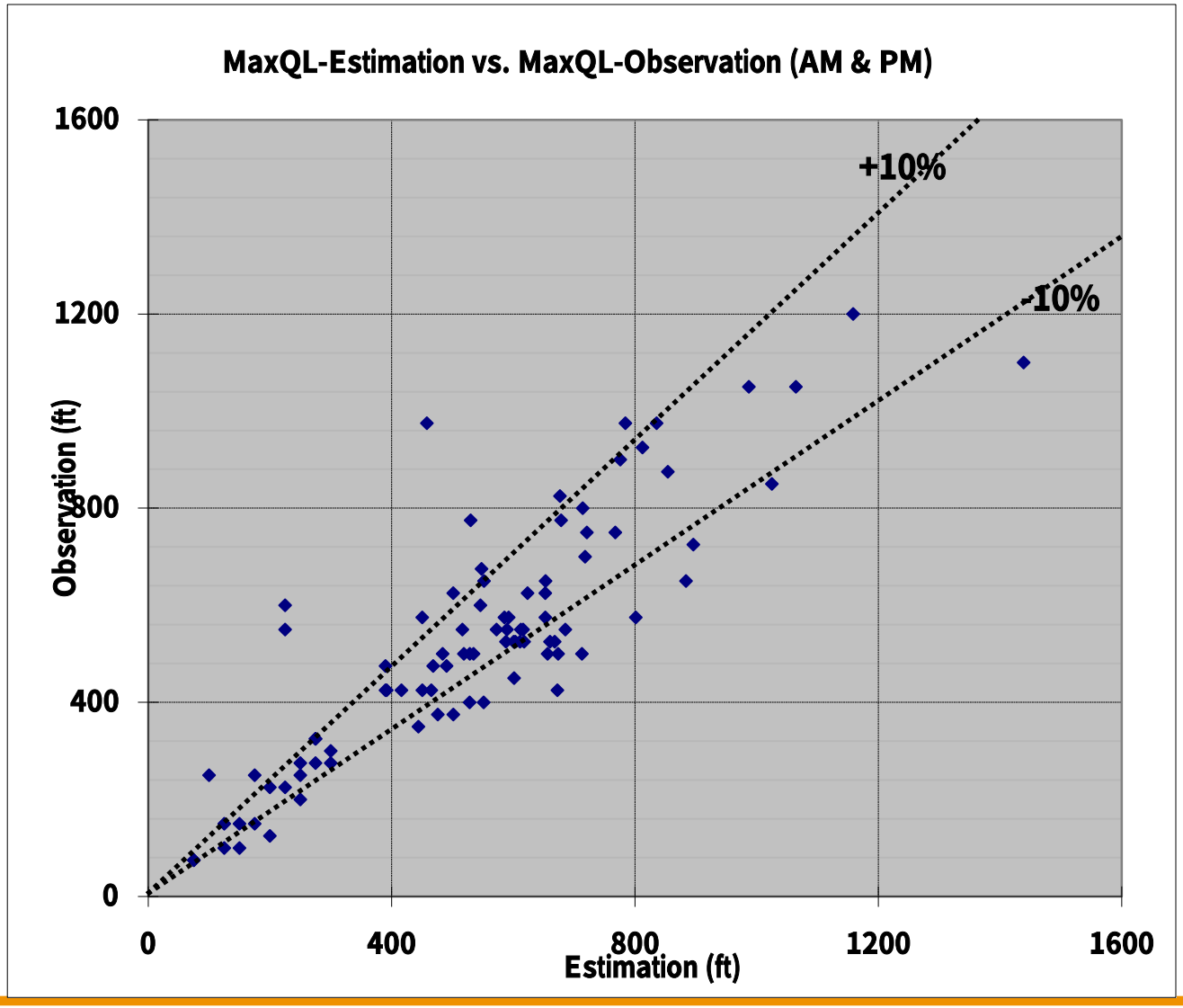
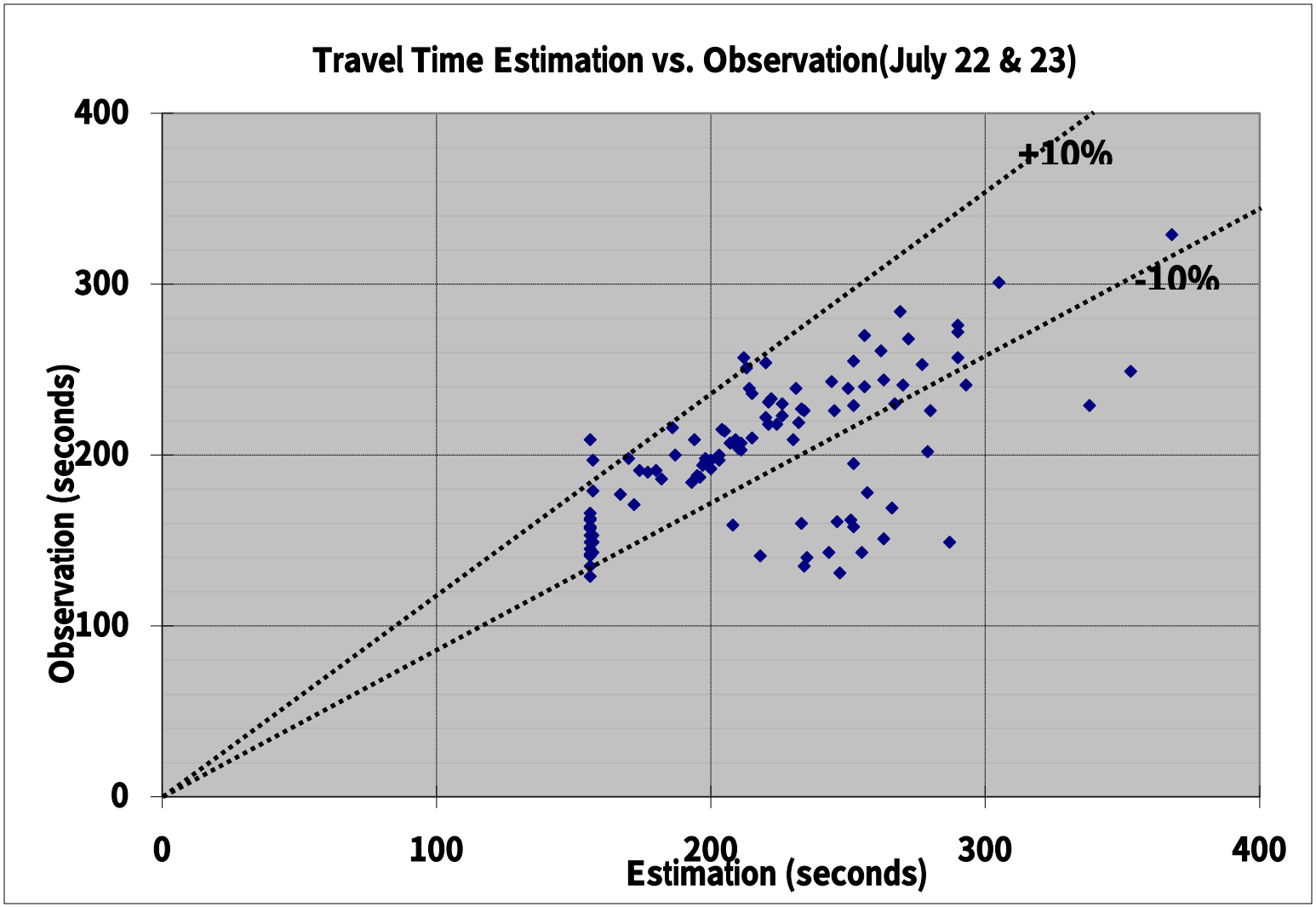
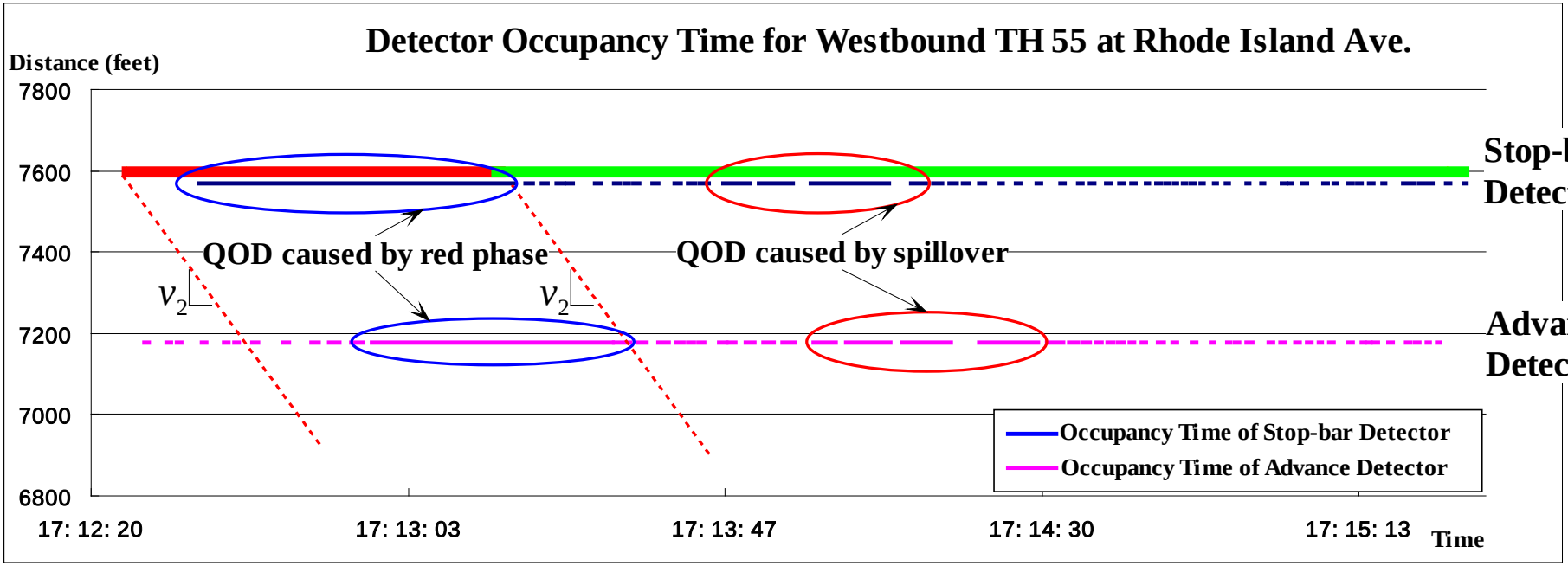


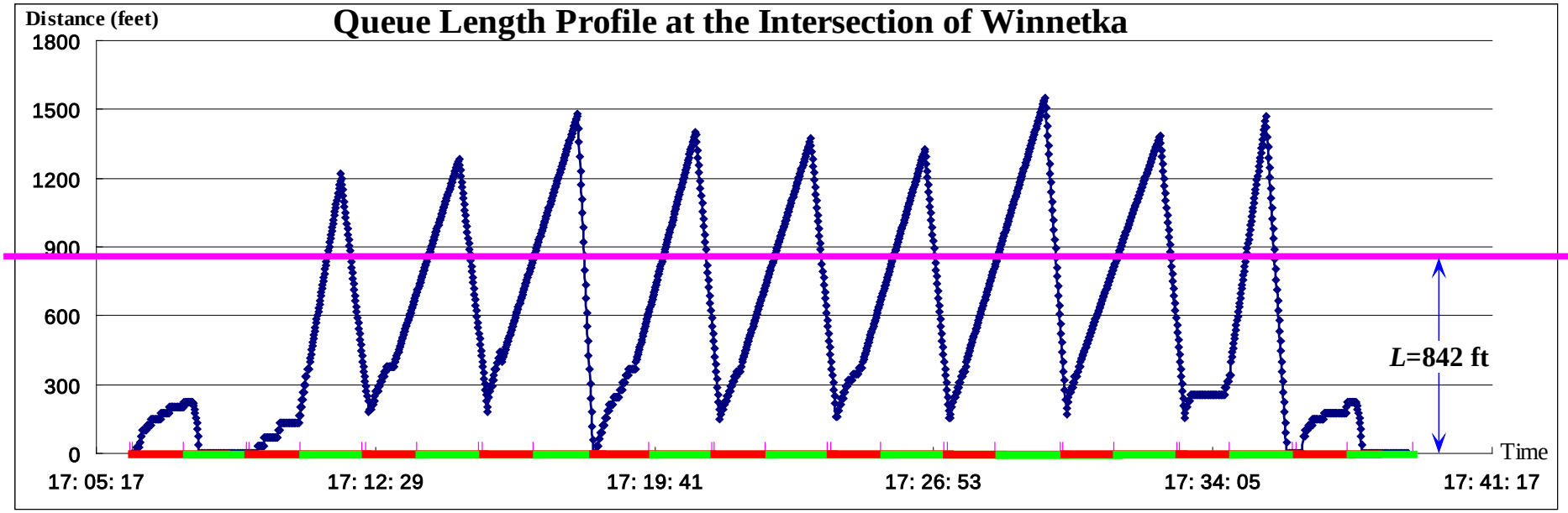
Results – Travel Time



Identification of Spillover



Queue Profile for Downstream Intersection



Expanded Capability of SMART-SIGNAL

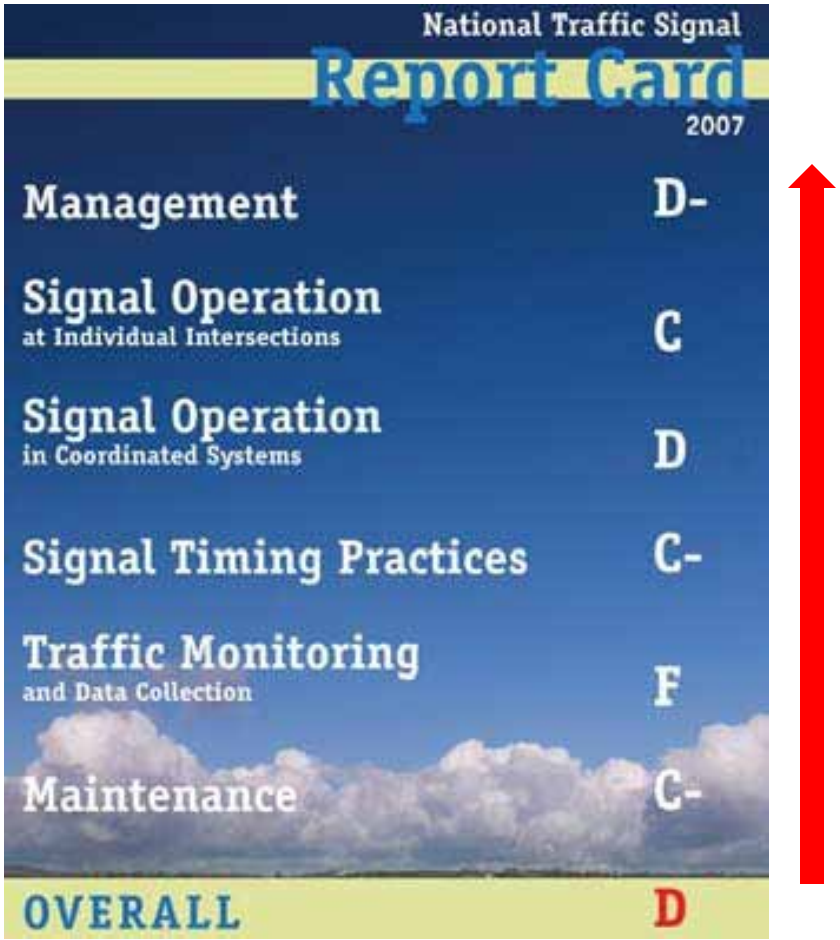
- **Fine-tuning signal timing parameters**
  - **Offsets fine-tuning**
- **Adaptive control under oversaturated conditions**
  - **Integrated Corridor Management**
  - **Large directional flow diverted from freeway**

Lessons Learned

- Although traffic is traditionally modeled as “continuous flow”, traffic, after all, is discrete.
- Measuring traffic flow parameters using the data collected at the individual vehicle level
- Don’t aggregate data before useful information being derived
- Technological advances support such data collection at affordable prices

Closing Remarks: Let's Raise the Floor and Improve the State-of-the-Practice

- There are no reason that we can not monitor or archive traffic signal data.
- Traffic signal parameters can be automatically fine-tuned based on the archived data.
- Adaptive signal control should work for both under-saturated and oversaturated conditions and it should be the norm.



Acknowledgements

THANK YOU!

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SMART-Signal Web Site:
http://signal.umn.edu